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Some Studies on Aluminium – Fly Ash Composites Fabricated by Two Step Stir Casting Method

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Abstract

Development of lightweight materials has provided the automotive industry with numerous possibilities for vehicle weight reduction. Progress in this area depends on the development of materials, processing techniques, surface and heat treatments. Since fuel consumption relates directly to vehicle weight, reducing weight can improve the fuel usage and price-to-performance ratio. Aluminium matrix ceramic reinforcement composites have attracted increasing attention due to their combined properties such as high specific strength, high stiffness, low thermal expansion coefficient and superior dimensional stability at elevated temperatures as compared to the monolithic materials. Aluminium reinforced with conventional ceramic materials such as SiC / Al_2O_3 are gradually being implemented into the production of pistons, cylinders, engine blocks, brakes and power transmission system elements in automobile industry. Fly ash (SiO_2, Al_2O_3, Fe_2O_3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituents) is one of the most inexpensive and low density material which is abundantly available as solid waste byproduct during combustion of coal in thermal power plants. The present investigation has been focused on the utilization of fly ash in useful manner by dispersing it into aluminium to produce composites by a two step stir casting method to overcome the cost barrier for wide spread applications in automotive systems. An attempt has also been made to investigate its microstructure, mechanical, wear and corrosion behavior of composites.

Keywords: Aluminium matrix composites, fly ash, wear behaviour and corrosion of MMCs

1. Introduction

Metal Matrix Composites (MMCs), particularly aluminium matrix ceramic reinforcement composites have emerged as a potential material for automotive and aerospace industries. In this study, fly ash

particles which are extracted from residues generated in the combustion of coal were chosen as reinforcement material. India produces about 110 million tons of fly ash per year from burning about 250 million tons of coal for electric power generation. Apart from energy and cost savings, green house gases that are generated during the production of Al may be significantly reduced by decreasing the production of Al by fly ash substitution. Among various processing techniques, stir casting appears to be most promising route for production of aluminium matrix composites because of simplicity and ability to manufacture composites on an industrial scale economically. In any production process, superior quality of the product can be achieved only when the process is run with the optimum parameters. Mechanical properties of composites are affected by the size and shape of the matrix and reinforcement materials, weight fraction of the reinforcement as well as reaction at the interface. Interfacial strength between the matrix and reinforcement plays a significant role in determining the properties of MMCs. These aspects have been discussed by many researchers.

Fly ash particles were incorporated into the molten Al they were observed to be floating on the molten Al surface due to the high surface tension which leads poor wettability.Since the gas layers at the surfaces of the particles can cause the buoyant migration, mechanical stirring can be done in a semi solid state rather than in the completely liquid state in order to break away the gas layers thereby reducing surface tension.Wettability can be improved by increasing the surface energies of the solids, decreasing the surface tension of the liquid matrix alloy and decreasing the solid/liquid interfacial energy at the reinforcement matrix interface. Magnesium which acts as a powerful surfactant as well as a reactive element, in the aluminium alloy matrix seems to fulfill all the above three requirements. Important role played by the magnesium during the composite synthesis is the scavenging of the oxygen from the dispersoid surface, thus thinning the gas layer and improving wetting action with the surface of the dispersoids.As concluded from previous research studies the strengthening of aluminium alloys with a dispersion of fine particulates strongly increases their potential in tribological and structural applications.

Rohatgi [5] reported that with the increase in volume percentages of fly ash, hardness value increases in Al–fly ash composites. He also reported that the tensile strength and elastic modulus of Al composites increases with increase in volume percentage (3–10%) of fly ash. Aghajanian and co researchers [6] have studied the Al_2O_3 particle reinforced Al MMCs and reported improvement in elastic modulus, tensile strength, compressive strength and fracture properties with an increase in the reinforcement content. Sarkar, Sen and Mishra [10] have studied Al– fly ash composite produced by impeller mixing and concluded that up to 17 wt% fly ash could be reinforced by liquid metallurgy route and also the addition of magnesium increases the wettability which leads mechanical properties such as hardness, tensile strength and the wear resistance. Guo and Rohatgi [12] observed that a slight decrease in density and strength of Al composites with increasing weight per cent of fly ash while hardness increased slightly up to 10 wt % fly ash, beyond 10 wt % a decrease was reported.

Radhakrishna and Ramachandra [21] have investigated the effect of fly ash on sliding wear, slurry erosive wear and corrosive behavior of aluminium matrix composites produced by stir casting method and concluded that Al (12 wt% Si) -15 wt% of fly ash particulate composite improved the abrasive wear resistance however the corrosion resistance decreased as fly ash content increases.Sudarshan and Surappa [22, 23] have synthesized A356 Al–fly ash particle composites and studied on dry sliding wear .They concluded that the addition of 6% of fly ash particles into A356 Al alloy showed lower wear rates at low loads (10 and 20 N) while 12% of fly ash reinforced composites showed lower wear rates compared to the unreinforced alloy in the load range 20–80 N.Corrosion wear of composites is a critical design criterion. Aylor and co researchers [24] stated that pitting corrosion on Al-SiC composites was observed predominantly at the interface between the Al and SiC.

Feng and co researchers [25] analyzed the pitting corrosion behaviour of Al-SiC 2024 composites and attributed the corrosion of the composites to pit formation at the Al-SiC interface. Rohatgi, Weiss, and Nikhil Gupta [11] have suggested that Al- fly composites could be used for automotive and other applications due to their better mechanical properties.Al-fly ash composites offer many potential applications particularly for internal combustion engine pistons and brake rotors. Thus,

much research has been carried out on particulate metal matrix composites for tribological applications due to the advantages of MMCs such as excellent wear resistance, high load carrying capacity and light weight. Though aluminium alloys are restricted in their tribological behaviour, it has been observed by the various researchers that increasing the ceramic reinforcement particles content could improve the wear resistance.

Hence application of aluminium matrix composites is gradually increasing in the automotive industries in making pistons, cylinder heads and connecting rods where the tribological properties of the material are very important.

Wear resistance of particulate composites significantly depends on the grit size, hardness, weight fraction and distribution of reinforcement particles, properties of matrix material, interfacial bonding between the matrix and reinforcement particles and experimental conditions such as hardness of the counter surface, applied load, sliding distance and sliding speed. The present work aims to investigate microstructure, mechanical, wear and corrosion behaviour of fly ash particle reinforced commercial aluminium composites fabricated by a two step stir casting method.

2. Experimental Work

In this study, 99.5 % pure aluminium ingot was used as the matrix material and fly ash particles with average size of (50-100µm) was used as the reinforcement and its chemical composition is shown in the table 1.

Table 1: Chemical composition of fly ash

Compound	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
%	54.27	34.73	6.1	2.4	2.1

In this research, Al - fly ash composites were produced varying percentage of fly ash (ie 5, 10, 15, 20, 25 wt %) by two step stir casting method. Stir casting setup is shown in Fig.1

Figure 1: Stir casting setup

The fly ash particles were preheated to 600˚C for 2 hours in a separate muffle furnace to remove the moisture content. Aluminium was charged in to the graphite crucible, and the furnace temperature was raised up to liquidus temperature 670˚C in order to melt the Al scraps completely and further the melt temperature was dropped to 620˚C to obtain a semi solid state.1.5 wt% Magnesium

and then preheated fly-ash particles were added into the crucible. Mg was added to the melt to promote the wetting action between Al matrix and fly ash reinforcement particles.

The molten Al composite slurry was stirred with a stirrer at a speed of 300 rpm after obtaining the semi- solid state for 10 minutes. Then the slurry was reheated to liquidus temperature of Al and the second step stirring was started in a liquid state for 5 minutes until the slurry was poured in a mould to solidify. The impeller was placed 1/3rd height from the bottom of the crucible. Since high torque was needed in mixing of the composite slurry in semi solid state, a variable torque - speed controlled mechanical stirrer was employed. Argon gas was blown at the rate of 2CC/min in to the furnace during the process to prevent oxidation of aluminium and magnesium. The melting was done in an electrical resistive furnace (2kW-1Kg capacity). Temperatures were measured with a thermocouple (+/- 3 K accuracy).

3. Microstructure Analysis

Optic microscope and Scanning Electronic Microscope (SEM) were employed to analyze the microstructure and also the wear surface profile to decide the wear mechanism of the material. Samples were mechanically polished using standard metallographic practices and etched with Keller's regent prior to micro structural examination.

4. Mechanical Properties

4.1. Density

Density of the composite specimens was obtained experimentally by the Archimedes principle. Theoretical density was calculated applying the rule of mixtures according to the weight fraction of reinforcement.

4.2. Hardness

Hardness test was performed on Al and composite specimens. The hardness values of the specimen were measured using Brinell hardness testing system with 10mm diameter at a load of 500 kg. The loading time was 30 seconds. Three readings were taken on each specimen to eliminate possibility of segregation and mean value was taken as the hardness of the composite.

4.3. Tensile and Compressive strength

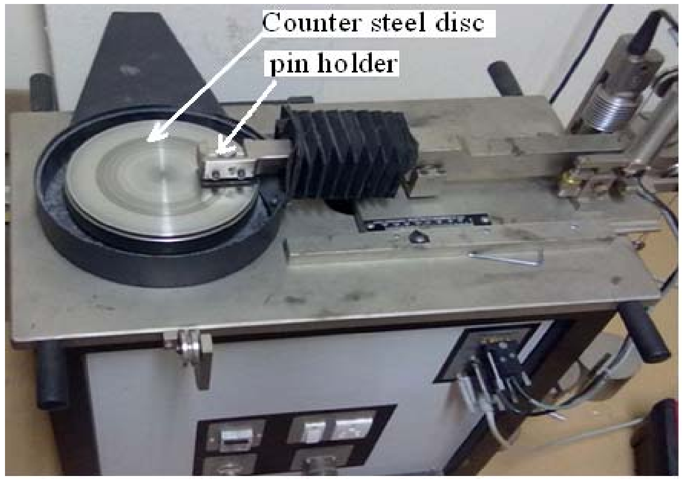
Tensile and compressive strength tests were carried out on Al specimens and composites using a computerized UTM testing machine as per the ASTM E-8 standards. Three samples were tested for each composition and mean value was taken as the tensile and compressive strengths.

5. Dry Sliding Wear

A cylindrical pin of size 10mm diameter and 15mm length Al and composite specimens were prepared and loaded in a computer interfaced pin- on -disc wear testing rig as shown in Fig.2. Before testing, the surface of the specimens was polished by using 1000 grit paper. The rotating disc was made of EN 32 steel of diameter 75 mm and hardness of 65HRC. Wear tests were carried out at room temperature for 20 minutes.

The test parameters used were as follows:
Normal loads: 5, 15 N.
Sliding speeds: 0.5, 1.0 m/s.

Figure.2: Pin- on -disc wear testing rig



6. Corrosion Studies

Corrosion is essentially an electrochemical process in which an oxidation reaction occurs at the anode and a reduction reaction occurs at the cathode.

The basic methodology is to measure the current flow in the electrolyte medium, which is proportional to corrosion rate with reference to potential applied. Corrosion tests were conducted for both unreinforced Al and composite specimens with varying weight % of fly ash content (5%, 10%, 15%, 20% and 25%).

Al and Al – fly ash composite specimens were subjected to corrosion test in 4% NaCl electrolyte solution at a pH of 3 using a standard Gill AC series-903 potentiostat.A typical equipment consists of Applied Corrosion Monitoring (ACM) Gill AC instrument and electrochemical cell which consists of NaCl electrolyte, a reference calomel electrode, a platinum auxiliary electrode and a working electrode of the specimen.

The specimens were machined to 20 mm dia and 20 mm length and were ground using 600grit emery paper, rinsed in distilled water and methanol to remove surface contaminants, and finally dried.

7. Results and Discussion

Al - fly ash composites were successfully produced by a two step stirring method which ensures homogenous particle distribution

7.1. Mechanical Behaviour

The graph of theoretical and experimental densities of the composites according to the fly ash content is shown in Fig.3.

Generally the fly ash particles are having low density in nature. In the present study precipitator type fly ash was used with a density less than 2.2 g/cm^3.The density of the composite specimens was determined experimentally by the Archimedes principle. The small pieces cut from the specimens were weighed first in air and then water and density values were calculated using the following expression.

$$\rho = \frac{\text{weight in air}}{(\text{weight in air - weight in water})} \times \rho_{water}$$

Theoretical density values were determined using the rule of mixtures relation. The experimental density values of the Al-fly ash composites decreased linearly with addition of fly ash particles. The decrease in density of composites can be attributed to lower density of fly ash particles than that of the unreinforced Al.It was also noted that the theoretical values closely matches with the

experimental values when the fly ash content is less than 20 wt%. It indicates that the interface between matrix and reinforcement was almost perfectly bonded the prepared castings are dense and sound. However when the fly ash content increases beyond 20 wt%, there is a mismatch between the theoretical and measured density values due to increased porosity and particle clustering.

Figure 3: Density of the Al and Al- fly ash composites at various Wt% of fly ash particles

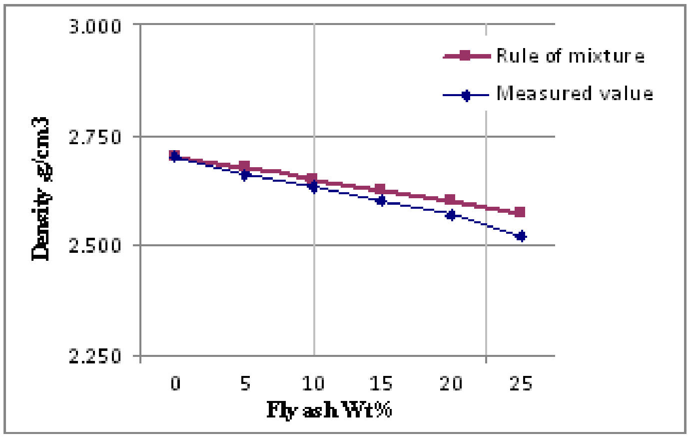


Figure 4: Hardness of the Composites at various Wt% of fly ash particles

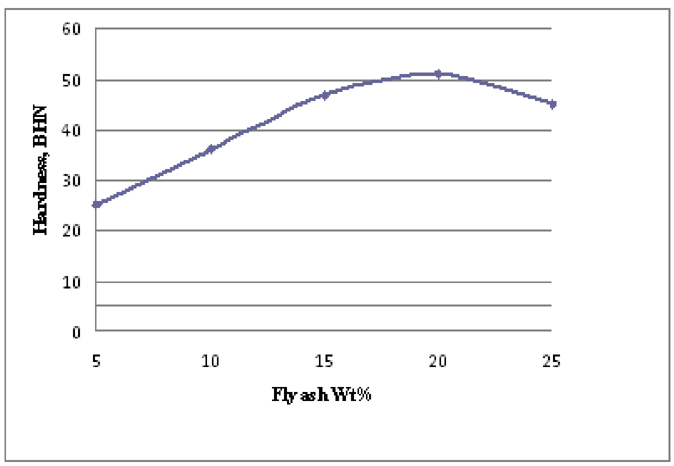


Figure 5: Tensile strength of the Composites at various Wt% of fly ash particles

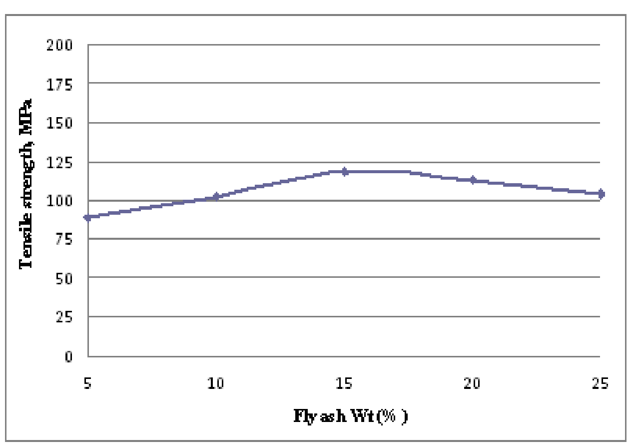


Figure 6: Compressive strength of the Composites at various Wt% of fly ash particles

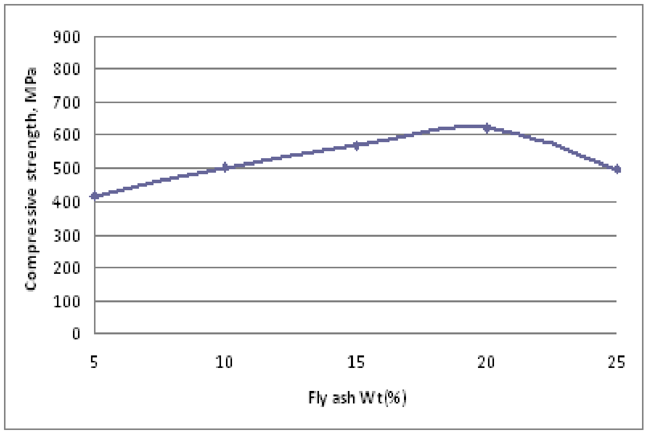


Table 2: Mechanical properties of Al and Al -fly ash Composites

Fly ash (wt)	Density (g/cm^3)	Hardness (BHN)	Tensile Strength (MPa)	Compressive Strength (MPa)
0%	2.700	19	77	337
5%	2.661	25	89	418
10%	2.633	36	102	501
15%	2.600	47	118	568
20%	2.569	51	113	622
25%	2.523	45	104	497

The results of the hardness test (Table.2) shows the values of hardness with the weight fraction of fly ash. As seen from Fig.4, an increasing trend of hardness was observed with increase in weight fraction of fly ash particles up to 20%.Beyond this hardness trend started decreasing. Incorporation of fly ash particles up to 20wt% significantly improves the hardness of the Al matrix. The presence of hard fly ash particles in the composites enhances the dislocation density which resists the deformation when it is subjected to strain. When the fly ash content increased from 5% to 20 wt %, hardness increases from 25 BHN to 51 BHN.It can be explained by the fact that the fly ash particles possess higher hardness than the aluminium.

Tensile strength tests were performed and the results of the test are shown in Fig.5. Results show that the tensile strength of composites is higher than that obtained for the unreinforced Al. Tensile strength of unreinforced Al is 77 MPa and this value increases to a maximum of 113MPa for Al- 15 wt% fly ash composite which is about 35% improvement over that of the unreinforced Al matrix. When the fly ash content increased from 20% to 25%, tensile strength decreases from 113 MPa to 104 MPa.It was observed that in probably due to clustering of the reinforcement particles the composites containing more than 15wt% of fly ash particles the rate of increase in tensile strength decreases significantly.

Results of the compression tests are shown in Fig.6. Results revealed that the incorporation of fly ash particles significantly improves the compressive strength of Al matrix. However the compressive strength of the composites begins to drop when the fly ash content increased from 20 % to 25 wt%. Beyond 20 wt%, the fly ash particles interact with each other due to particles clustering which deteriorates the properties. It may be noted that the composites subjected to compressive stress, Al matrix around fly ash particles flows away in the direction perpendicular to the applied load which reduces load transfer ability of the matrix.

Thus, it can be concluded that the mechanical properties such as density, hardness, tensile and compressive strengths of the composites increases by increasing fly ash content. Addition of magnesium improves the wettability between the fly ash particles and enhances the mechanical

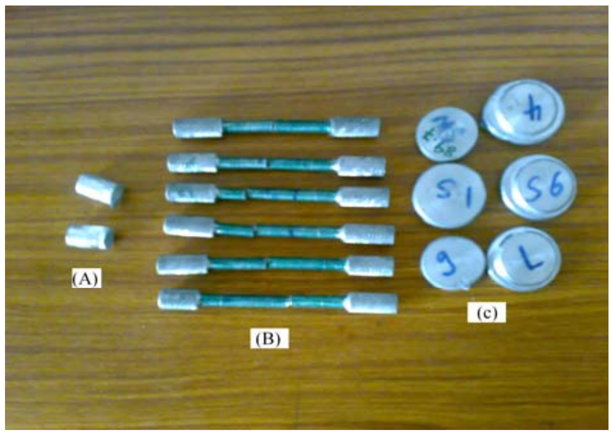
properties of the composites by solid solution strengthening. In addition, mechanical stirring in the semi solid state enhances the uniform distribution between them.

It was also observed from the Table.2 that the trend of declining mechanical properties such as hardness, tensile and compressive strengths of the composites with increasing fly ash content beyond 15 – 20 wt%.

Agglomeration of fly ash particles could reduce the interfacial bonding between Al and fly ash particles.

The diffusion of Mg at the Al- fly ash interface could also result in Mg depletion from the matrix, accounting for the reduction of the Mg_2Si particle size which leads to a decrease in solid solution strengthening. Hence results in the decline in the mechanical properties of the composites.

Figure7: Few tested specimens (A: Wear; B: Tensile strength; C: Hardness)



7.2. Sliding Wear Behaviour

Average wear loss of the composites were examined as a function of fly ash particle content at various load and sliding speed conditions against carbon steel as illustrated graphically in Figures. 8 and 9.Few tested wear pin specimens are shown in Fig.7.

Wear, the progressive loss of material from the sliding surfaces of the elements of a tribo-system can be determined in terms of weight loss. Material properties of the sliding elements, applied load and sliding speed determine the wear rate. Wear resistance of the Al- fly ash reinforced composites is increased compared to the unreinforced Al at all sliding speed and load conditions. Drastic decrease in wear loss was observed with the incorporation of reinforcement content.

Figure 8: Wear loss of Al specimen and Al –fly ash composites as a function of sliding speeds 0.5 m/s and 1m/s at constant load 5N

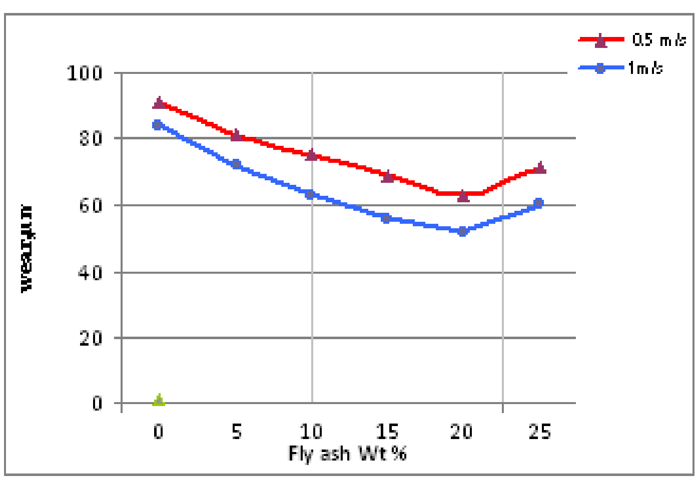
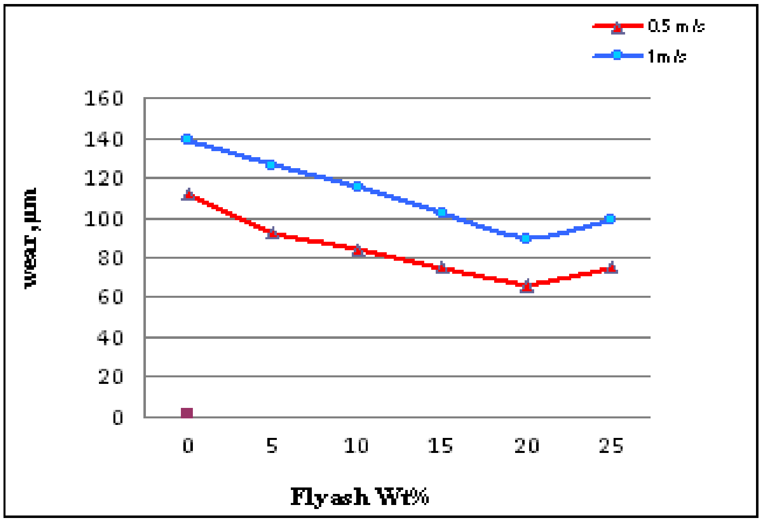


Figure.9 : Wear loss of Al and Al –fly ash composites specimen as a function of of sliding speeds 0.5 m/s and 1m/s at constant load 15N



The decreasing tendency in wear rate of the Al- fly ash composites was observed from the Fig.8 when the sliding speed increases from 0.5 m/s to 1m/s at low load (5N) and lower concentration of fly ash (<20 wt %). As the sliding speed increases, the surface of the counter face reacts to form ferrous oxide (Fe_3O_4) along with aluminum oxide (Al_2O_3) and a Mechanical Mixing Layer – MML between the composite pin and the counter face was formed. It is obvious that the work hardening of the aluminium occurs during the sliding action and also formation of iron oxide film (Fe_3O_4) on the surface of the pin which enhances the wear resistance.

Fig.9 indicates that the wear rate of the Al increased as the sliding speed increases and the same trend of was observed in Al – fly ash composites at higher load 15N

At higher speed (1m/s) and load (15 N) conditions, the thermal softening effect of the Al lowers the interfacial bond between the Al and fly ash materials and also the protective oxide layer smashed out during the sliding action resulting in higher wear loss . By superimposing the Fig.8 and Fig.9, it can be observed that the wear rate of the Al and Al- fly ash composites increases as the load increases from 5 N to 15 N. The obtained results are inline with the other researchers [23]. Further, from the Figures 8 and 9, trend in wear resistance can be found to be increasing with increase of fly ash content in the composites. This increase in wear resistance of the composite is due to the reason the reinforcement material is much harder than that of the matrix material.

Wear grooves and scratches along the sliding direction were smaller due to the presence of fly ash particulates. This shows that the presence of fly ash in the matrix improves resistance to wear. Applied load affects the wear behaviour of composites and is the most dominating factor in controlling the wear rate.

Since the Al matrix is much softer than the carbon steel disc, the steel penetrates to larger depth into the surface and cuts severely, causing plastic deformation of the surface resulting in a great amount of material loss. The worn surface of the Al – wt 5% fly ash shows little plastic deformation as shown in Fig.10.

Worn surface of the Al composite with 25 wt% fly ash was characterized by many pull-out and exposures of the fly ash particles and more wear debris was observed which indicated the poor interfacial strength between the Al matrix and fly ash particles. Large grooves and scratches appeared on the worn surfaces as shown in Fig.11 and there was no indication of plastic deformation.

Figure 10: The worn surface of the Al – wt 5%fly ash with a normal load of 5N with 1m/s Sliding velocity

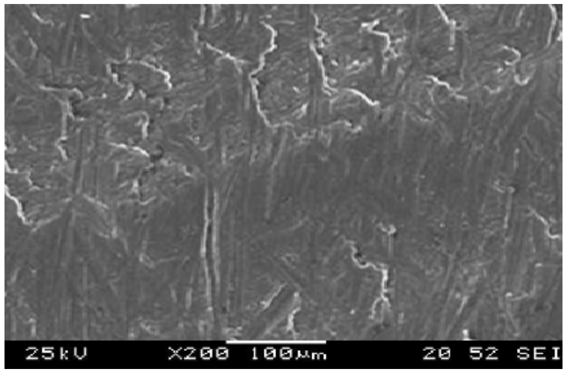
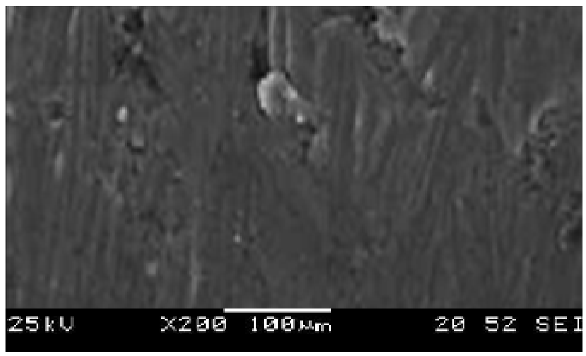


Figure 11: The worn surface of the Al – wt 25%fly ash composite with a normal load of 15N and 0.5m/s Sliding velocity.



The lowest wear loss was obtained for composite with 20wt% fly ash compared to composites reinforced with 5 wt %, 10 wt % and 15 wt % fly ash.Al-20wt% fly ash composite demonstrated wear resistance approximately 7 times higher than that of unreinforced Al at 1 m/s sliding speed and 5N load conditions. This is because incorporation of fly ash particles have increased the hardness of Al considerably (Table 2) .This increase in wear resistance can also be attributed to a better interfacial bonding between Al and fly ash particles and thus helps in preventing the damages caused due to sliding action. Incorporation of 20wt% fly ash particles to the Al matrix was very effective in reducing its wear loss. This is because of the strong interfacial bond which plays a vital role in transferring loads from the Al matrix to the hard fly ash particles. As the fly ash content increases beyond 20 wt% the wear loss increased with increasing the load. This may be due to clustering of fly ash particles and poor interfacial bonding between Al matrix and fly ash particles.

When the two surfaces are in sliding contact, wear mechanisms such as surface abrasion, oxidation, delamination and adhesion may happen either separately or in combination. The surface morphologies of the worn composites indicate the following.

1. 1.At low loads, fly ash particles support the load and prevents Al matrix have direct contact with the counter part thus helps in preventing the damages caused due to sliding action. Abrasion wear mechanism becomes dominant under this condition.
2. 2. Higher applied load results in stresses which exceed fracture stress of fly ash particles, these particles lose their capacity to sustain the load. In addition the hard fly ash particles create scars on the surface of the steel counter face which in turn causes higher wear rate of the composite. The worn out particles also act as third body abrasives, initiate friction and could penetrate the opposing surfaces in a contact zone which lead micro ploughing action at the interface.
3. 3. At lower sliding speeds abrasion is dominant, while at higher sliding speeds delamination and adhesion dominate.

It follows from the above observations that the main wear mechanism at higher loads and high sliding speeds is delaminating wear causing excessive fracture of the reinforcement and the matrix, resulting in deterioration of the wear resistance of the composites.

When the composite is subjected to the higher applied load with higher sliding speed, cracks on the surface propagates in the subsurface which brings loss of material from the worn surface in the form of flakes or thin sheets. Considerable amount of Iron debris is also transferred from the counter face to the composite pins.

Delamination was observed to be more extensive under the higher load of 20N.

7.3. Corrosion Wear Behaviour

The corrosion wear of composites is influenced by several factors such as porosity, high dislocation densities at the matrix-reinforcement interfaces, the presence of intermetallic compounds and interfacial reaction products, and the electrical conductivity of the reinforcing phases.

Corrosion wear was evaluated in terms of mm/year for the fabricated Al and Al – fly ash composites with varying proportion of fly ash content using Potentiostat corrosion testing rig which is shown in Fig.12.

Figure 12: Potentiostat corrosion testing rig

Electro chemical polarization reactivation curves (EPR) were obtained with the help of ACM software.

Corrosion current and corrosion rate were determined using the following expression specified by ASTM G1-90.

$$\text{Corrosion rate in mm/year} = [I_{corr} \times \text{Metal factor}]/1000$$

where,

$$I_{corr} = \frac{(ba \times bc)}{[2.3 \times Rp \times (ba + bc)]}, A/m^2$$

ba is anodic Tafel slope in Volts

bc is the cathodic Tafel slope in Volts

Rp is the polarization resistance in W/m^2

Metal factor $= (t \times K)/\rho$

Where, t (seconds in year), ρ is the specimen density in g/ cm^3 ,K is the electrochemical equivalent in g/coulombs,

$$K = \frac{\text{weight \% of element} \times \text{atomic weight of element}}{96487 \times \text{Valency of element}}$$

It was observed from the EPR curve that Al-15wt% fly ash composite indicates a decrease of the corrosion potential and an increase of the corrosion current density than that of EPR curve of Al. It

may be noted that the high corrosion density of Al- fly ash composites increases the rate of Al dissolution due to pH variations at the interface. Results show that the corrosion and pitting potentials of Al were superior to Al- fly ash composites.

Figure.13: Corrosion rate of Al and Al- fly ash composites

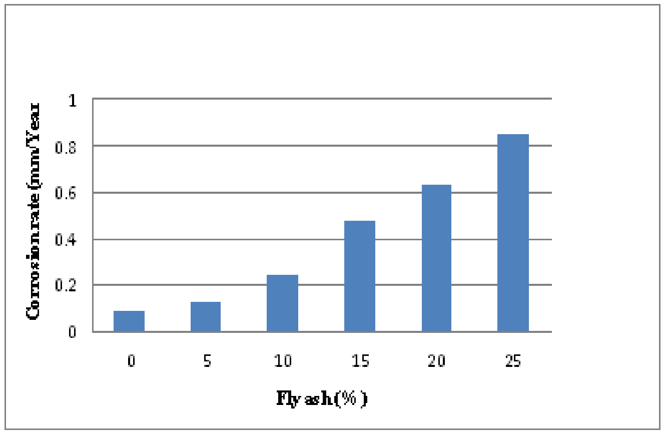


Fig.13 shows that Al and Al- 25 wt% fly ash composite had the lowest and highest corrosion rate, respectively. The corrosion rate of Al- 25wt%fly ash composite is about 10 times higher than that of the Al.

According to the general qualitative classification of corrosion rates, moderate corrosion behaviour is seen when the fly ash content is less than 15 wt%.

Figure 14: SEM micrograph of Al specimen immersed in 3.5wt % NaCl solution

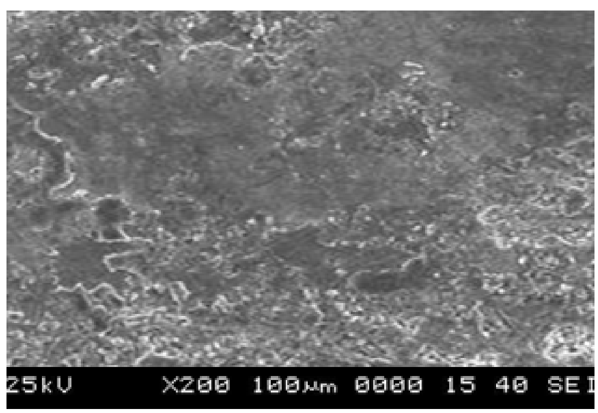
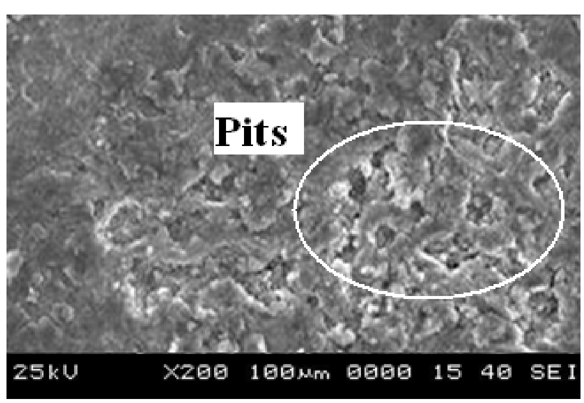


Figure 15: SEM micrograph of Al-15wt. %fly ash composite specimen immersed in 3.5wt % NaCl solution



SEM micrographs of Al and Al- fly ash specimens are shown in Figures 14 and 15 respectively. SEM studies revealed that more pits are formed on Al-fly ash composite than on Al. The micrograph (Fig.15) reveals the presence of cracks and pits which are indicative of localized corrosion. Incorporation of fly ash to the Al matrix develops discontinuities in the protective oxide layer which leads to pitting corrosion.

Incorporation of fly ash in the Al matrix releases Fe- rich intermetallic phases such as Al_3Fe / Al_6Fe which behaves as cathode. The occurrence of intermetallic phase at the interface provide a platform for the electron exchange needed for oxygen reduction and increases the anodic reaction at a higher rate in the composites as compared to an aluminium.Hence, the formation of galvanic couples between the intermetallics and the Al matrix causes dissolution of Al matrix and finally the detachment of Al particles lead formation of pits. When the fly ash content increases beyond 10 wt%, corrosion resistance of the composites is drastically increased .This can be attributed to the formation of more intermetallic clusters, porosities and voids at the interface.

8. Conclusions

Al –fly ash composites were successfully fabricated by two step stir casting process with homogenous distribution of fly ash particles in the Al matrix. Wetting of fly ash particles with the Al matrix was further improved by the addition of 1.5 wt%Mg.

Based on the experimental observations the following conclusions have been drawn.

1. The density of the composites decreased with increasing fly ash reinforcement content. Hence Al- fly ash composites can be used in applications where weight reductions are desirable.
2. Hardness, tensile strength and compressive strength were determined for the test materials. Increasing fly ash content resulted in increase in the tensile strength of the Al. However, the tensile strength begins to drop when the fly ash content exceeds 15wt% due to the decrease in solid solution strengthening and particle clustering.
   Hardness and compressive strength of composites were found to increase with increased fly ash content. Above 20 wt% of fly ash, both hardness and compressive strength of composites begins to decrease.
3. Wear resistance of the commercial Al was considerably enhanced by the addition of fly ash particles and the wear resistance of the composites was much superior to the unreinforced aluminium over the entire load range tested under dry sliding conditions.
   This may be due to the favorable effect of the fly ash particles which is a dominating factor affecting the wear resistance. However the addition of only 20wt% fly ash particle to the Al was very effective to reduce its wear loss.
4. It was observed that the high proportion of fly ash reinforcement shows the poor resistance to corrosion.

Moderate corrosion resistance is seen when the fly ash content is about 15 wt%

From the results it can be concluded that the Al-fly ash composites could be considered as an excellent material in sectors where light weight, enhanced mechanical properties and wear resistance are prime consideration especially in automobile applications.

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